(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 May 2002 (02.05.2002)

PCT

(10) International Publication Number
WO 02/35646 A1

(51) International Patent Classification[7]: H01Q 1/32

(21) International Application Number: PCT/EP00/10562

(22) International Filing Date: 26 October 2000 (26.10.2000)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **FRACTUS - FICOSA INTERNATIONAL, U.T.E.** [ES/ES]; Edificio Nexus, Gran Capitán 2, Despacho 303, E-08034 Barcelona (ES).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **PUENTE BALIARDA, Carles** [ES/ES]; Once Septiembre 24, E-08391 Tiana (Barcelona) (ES). **ROZAN, Edouard, Jean, Louis** [FR/ES]; Loreto, 13 B, Entlo 3, E-08029 Barcelona (ES).

(74) Agent: **CARPINTERO LOPEZ, Francisco**; Herrero y Asociados, S.L., Alcalá, 35, E-28014 Madrid (ES).

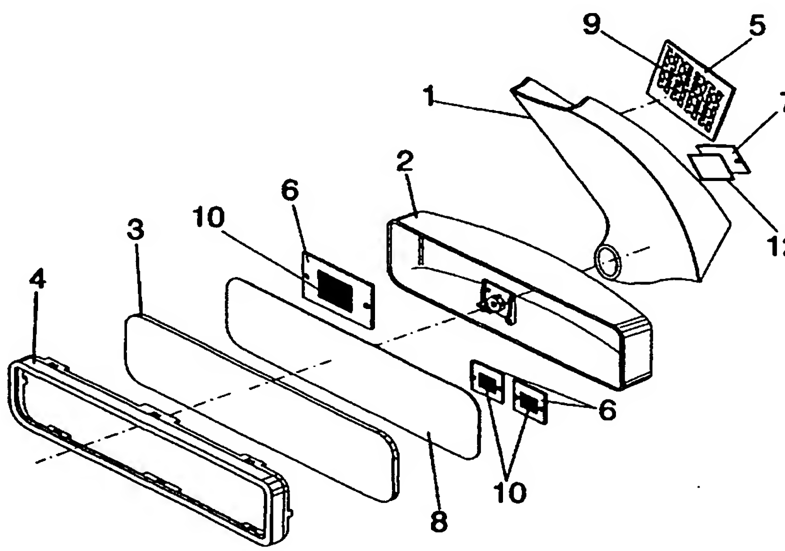
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *with amended claims*

[Continued on next page]

(54) Title: INTEGRATED MULTISERVICE CAR ANTENNA



(57) Abstract: This invention relates a multiservice antenna system integrated in a plastic cover fixed in the inner surface of the transparent windshield of a motor vehicle. The invention includes miniaturized antennas for the basic services currently required in a car, namely, the radio reception, preferably within the AM and FM or DAB bands, the cellular telephony for transmitting and receiving in the GSM 900, GSM 1800 and UMTS bands and for instance and the GPS navigation system. The antenna shape and design are based on combined miniaturization techniques which permit a substantial size reduction of the antenna making possible its integration into a vehicle component such as, for instance, a rearview mirror. At least a first antenna of the antenna system includes a conducting strip or wire, being shaped by a space-filling curve.

WO 02/35646 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTEGRATED MULTISERVICE CAR ANTENNA

DESCRIPTION

OBJECT OF THE INVENTION

This invention relates a multiservice antenna system integrated in a plastic cover fixed in the inner surface of the transparent windshield of a motor vehicle.

The invention includes miniaturized antennas for the basic services currently required in a car, namely, the radio reception, preferably within the AM and FM or DAB bands, the cellular telephony for transmitting and receiving in the GSM 900, GSM 1800 and UMTS bands and for instance and the GPS navigation system.

The antenna shape and design are based on combined miniaturization techniques which permit a substantial size reduction of the antenna making possible its integration into a vehicle component such as, for instance, a rearview mirror.

BACKGROUND OF THE INVENTION

Until recently, the telecommunication services included in an automobile were limited to a few systems, mainly the analogical radio reception (AM/FM bands). The most common solution for these systems is the typical whip antenna mounted on the car roof. The current tendency in the automotive sector is to reduce the aesthetic and aerodynamic impact of such whip

antennas by embedding the antenna system in the vehicle structure. Also, a major integration of the several telecommunication services into a single antenna is specially attractive to reduce the manufacturing costs or the damages due to vandalism and car wash systems.

The antenna integration is becoming more and more necessary as we are assisting to a deep cultural change towards the information society. The internet has evoked an information age in which people around the globe expect, demand, and receive information. Car drivers expect to be able to drive safely while handling e-mail an telephone calls and obtaining directions, schedules, and other information accessible on the world wide web (WWW).

Telematic devices can be used to automatically notify authorities of an accident and guide rescuers to the car, track stolen vehicles , provide navigation assistance to drivers, call emergency roadside assistance and remote diagnostics of engine functions.

The inclusion of advanced telecom equipments and services in cars an other motor vehicles is very recent, and it was first thought for top-level, luxury cars. However, the fast reduction in both equipment and service costs are bringing telematic products into mid-priced automobiles. The massive introduction of a wide range of such a new systems would generate a proliferation of antennas upon the bodywork of the car, in contradiction with the aesthetic and aerodynamic trends, unless an integrated solution for the antennas is used.

This year, patent PCT/EP00/00411 proposed a new family of small antennas based on the curves named as space-filling curves. An antenna is said to be a small antenna (a miniature antenna) when it can be fitted into a small space compared to the operating wavelength. It is known that a small antenna features a large input reactance (either capacitive or inductive) that usually has to be compensated with an external matching / loading circuit or structure. Other characteristics of a small antenna are its small radiating resistance, small bandwidth and low efficiency. This is mean that is highly challenging to pack a resonant antenna into a space which is small in terms of the wavelength at resonance. The space-filling curves introduced for the design and construction of small antennas improve the performance of other classical antennas described in the prior art (such as linear monopoles, dipoles and circular or rectangular loops).

The integration of antennas inside mirrors have been already proposed. Patent US4123756 is one of the first to propose the utilization of conducting sheets as antennas inside mirrors. Patent US5504478 proposed to use the metallic sides of a mirror as antenna for wireless car aperture. Others configurations have been proposed to enclose wireless car aperture, garage opening or car alarm (Patent US5798688) inside mirrors of motor vehicles. Obliviously, these solutions proposed a specific solution for determinate systems, which generally require a very narrow bandwidth

antenna, and did not offer a full integration of basic services antenna.

Other solutions were proposed to integrate the AM/FM antenna in the thermal grid of the rear windshield (Patent n° WO95/11530). However, this configuration requires an expensive electronic adaptation network, including RF amplifiers and filters to discriminate the radio signals from the DC source and is not adequate for transmission like telephony signal due to the low antenna efficiency.

One of the main substantial innovation introduced in the present invention consists in using for instance a rearview mirror to integrate all basics services required in a car: radio-broadcast, GPS and wireless access to cellular networks. The main advantages of the present invention with respect to prior art are: first a full antenna integration with no aesthetic or aerodynamic impact; second a full protection from accidental damage or vandalism, and third a significant cost reduction.

The utilization of microstrip antennas is already known in mobile telephony handsets (Paper by K. Virga and Y. Rahmat-Samii, "Low-Profile Enhanced-Bandwidth PIFA Antennas for Wireless Communications Packaging", published in IEEE Transactions on Microwave Theory and Techniques in October 1997), especially in the configuration denoted as PIFA (Planar Inverted F Antennas. The reason of the utilization of microstrip PIFA antennas reside in their low profile, their low fabrication costs and an easy integration within the

hand-set structure. However, this antenna configuration has not been proposed to be used in a motor vehicle. Several antenna configurations claimed by the present invention to integrate a multiservice antenna system like inside an interior rearview mirror include the utilization of PIFA antennas.

One of the miniaturization techniques used in the present invention are based, as it has been said before on space-filling curves. . In some particular case of antenna configuration proposed in this invention, the antenna shape could be also described as a multi-level structure. Multi-level techniques have been already proposed to reduce the physical dimensions of microstrip antennas (PCT/ES/00296).

SUMMARY OF THE INVENTION

The present invention describes an integrated multiservice antenna system for vehicle comprising the following parts and features:

a) At least a first antenna of said antenna system includes a conducting strip or wire, said conducting strip or wire being shaped by a space-filling curve, said space-filling curve being composed by at least two-hundred connected segments, said segments forming a substantially right angle with each adjacent segment, being said segments smaller than a hundredth of the free-space operating wavelength, and said first antenna is used for AM and FM or DAB radio broadcast signal reception.

b) The antenna system can optionally include miniaturized antennas, for wireless cellular services such as GSM 900 (870-960 MHz), GSM 1800 (1710-1880 MHz) and UMTS (1900-2170 MHz).

c) The antenna system can include a miniaturized antenna for GPS reception (1575 MHz).

d) The antenna set is integrated within a plastic or dielectric cover, said cover fixed on the inner surface of the transparent windshield of a motor vehicle,

e) The upper edges of this plastic cover is aligned with the upper, lateral or lower side of the frame of said windshield, and a conducting terminal cable is electrically connected to the metallic structure of the motor vehicle for grounding the ground conductor of the antennas within the system.

In the present invention, one of the preferred embodiments for the plastic cover enclosing the multiservice antenna system is the housing of the inside rearview mirror, including the rearview mirror support and/or the mirror itself. This position ensures an optimized antenna behavior, i.e. a good impedance matching, a substantially omnidirectionnal radiation pattern in the horizontal plane for covering terrestrial communication systems (like radio or cellular telephony), and a wide coverage in elevation for the case of satellite communication systems such as for instance GPS.

The important reduction size of the antennas introduced in the present invention is obtained by using space-filling geometries. A space-filling curve can be described as a curve that is large in terms of physical length but small in terms of the area in which the curve can be included. More precisely, the following definition is taken in this document for a general space-filling curve: a curve composed by at least ten segments said segments forming an angle with each adjacent segment. Whatever the design of such space-filling curve is, it can never intersect with itself at any point except the initial and final point (that is, the whole curve can be arranged as a closed curve or loop, but none of the parts of the curve can become a closed loop). A space-filling curve can be fitted over a flat or curved surface, and due to the angles between segments, the physical length of the curve is always larger than that of any straight line that can be fitted in the same area (surface) as said space-filling curve. Additionally, to properly shape the structure of a miniature antenna according to the present invention, the segments of the space-filling curves must be shorter than a tenth of the free-space operating wavelength.

In the present invention, at least one of the antennas described in part by a space-filling curve is characterized by a more restrictive feature: said curve is composed by at least two-hundred segments, said segments forming a right angle with each adjacent segment, being said segments smaller than a hundredth of the free-space operating central wavelength. A possible antenna configuration is to use said space-

filling antenna as a monopole, where a conducting arm of said monopole is substantially described a said space filling curve. The antenna is, then, fed with a two conductor structure such as a coaxial cable, with one of the conductors connected to the lower tip of the multilevel structure and the other conductor connected to the metallic structure of the car which acts as a ground counterpoise. Of course, other antenna configurations can be used featuring as the main characteristic said space-filling curve, for example a dipole or a loop configuration. This antenna is suitable for instance for analogic (FM/AM) or digital broadcast radio reception, depending on the final antenna size as it is apparent to anyone skilled in the art. Said antenna features a significant size reduction below a 20% than the typical size of a conventional external quarter-wave whip antenna; this feature together with the small profile of the antenna which can be for instance printed in a low cost dielectric substrate, allows a simple and compact integration of the antenna structure into a car component such as the mounting of the inside rearview mirror. By properly choosing the shape of said space-filling curve, the antenna can be also used in at least certain applications transmission and reception in the cellular telephone bands.

Besides the key reduction of the antenna element covering the radio broadcast services, another important aspect for the integration of the antenna system into a small package or car component is reducing the size of the radiating elements covering the wireless cellular services. This can be achieved

for instance by using a Planar Inverted F Antenna (PIFA) configuration, consisting on connecting two parallel conducting sheets, said sheets separated either by air or a dielectric, magnetic or magneto-dielectric material, said sheets connected through a conducting strip near a one of the sheets corners and orthogonally mounted to both sheets. The antenna is fed through a coaxial cable, said coaxial cable having its outer conductor connected to first sheet, being the second shit coupled either by direct contact or capacitivelly to inner conductor of said coaxial cable. Although the use of PIFA antennas is known for handsets and wireless terminals, in the present invention said configuration is used advantageously for integrating a wireless service in the vehicle. The main advantage is that due to the small size, low profile and characteristic radiation pattern, the PIFA antennas are fully integrated in a preferred configuration into the housing or mounting of the inner rearview mirror, obtaining an optimum coverage for wireless networks, a null impact on the car aesthetics, and a reduced irradiation of the head and body of the car driver due to the protection of the mirror surface.

A further reduction of the PIFA antennas within the multiservice antenna system is optionally obtained in a preferred embodiment of the present invention by shaping at least one edge of at least on sheet of the antenna with an space-filling curve. It is known that the resonant frequency of PIFA antennas depends on its perimeter. By advantageously shaping at least a part of the perimeter of said PIFA antennas with a space-filling curve, the resonant frequency is reduced such

that the antennas for wireless cellular services in said preferred embodiment are reduced as well. The size reduction that can be achieved using this combined PIFA-space-filling configuration can be better than a 40% compared to a conventional, planar microstrip antenna using the same materials. The size reduction is directly related to a weight and cost reduction which are relevant for the automotive industry.

The coverage of the satellite system such as GPS is obtained by placing a miniature antenna close to the surface of the housing of the antenna system which is attached to the vehicle window glass. In the present invention, the space-filling technique or the multilevel antenna technique are advantageously used to reduce the size, cost and weight of said satellite antenna. In a preferred embodiment, a microstrip patch antenna with a high dielectric permittivity substrate is used for said antenna, being at least a part of the patch shaped either as a space-filing curve or a multilevel structure.

An important advantage of the present invention is the size reduction obtained on the overall antenna systems using space-filling techniques. This size reduction allows a full integration of the antennas for the current applications required in today and future vehicles (radio, mobile telephony and navigation) inside a rearview mirror. This integration supposes an important improvement of the aesthetic and visual impact of the conventional monopoles used in radio or cellular telephony reception and transmission in automotive market.

Other important advantage of the present invention is the cost reduction, not only in the material of the antenna, but also in the manufacturing an assembling of the motor vehicle. The substitution of the several conventional whip monopoles (one for each terrestrial wireless link) by the system of present invention supposes the elimination of mounting operations in production lines such as the perforation of the car bodywork, together with the suppression of additional mechanical pieces that ensure a solid and watertight fixture of the conventional whip antennas which are exposed to a high air pressure. Placing the antenna system inside the rearview mirror in the interior of the car do not requires additional operations in the final assembly line. Also, a weight reduction is obtained by avoiding the conventional heavy mechanical fixtures.

According to current practice in the automotive industry, the same rearview mirror can be used through several car models or even car families; therefore an additional advantage of the present invention is that the integrated antenna system is standardized for such car models and families as well. The same component can be used irrespective of the type of vehicle, namely a standard car, a monovolume, a coupe or even a roof-less cabriolet.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 represents a complete view of a preferred embodiment of the antenna system inside a rear-view

mirror. The rearview mirror includes a base support (1) to be fixed on the front windshield, a space-filling antenna for AM/FM reception (5), a set of miniature antennas (6) for wireless cellular system telephony transmitting or receiving GSM 900 (870-960 MHz) , GSM 1800 (1710-1880 MHz) and UMTS (1900-2170 MHz) signals, and a GPS antenna (7).

Figure 2: Another preferred embodiment of the present invention. The rearview mirror base support (1) to be fixed on the front windshield includes, a space-filling antenna for AM/FM reception (5), a set of miniature antennas (6) for wireless cellular system telephony transmitting or receiving GSM 900 (870-960 MHz) , GSM 1800 (1710-1880 MHz) and UMTS (1900-2170 MHz) signals, and a GPS antenna (7).

Figure 3: Detail of space-filling structure antenna for reception of AM/FM bands. The antenna is fed as a monopole and is placed inside a rearview mirror support. The antenna can be easily adapted for DAB system by scaling it proportionally to the wavelength reduction

Figure 4: Example of miniature a set of miniature antennas (6) for cellular telephony system for transmitting GSM 900 (870-960 MHz) , GSM 1800 (1710-1880 MHz) and UMTS (1900-2170 MHz). In this configuration, the antennas are composed by two planar conducting sheets, the first one being shorter than a quarter of the operation wavelength (10), and the second one being the ground counterpoise (8). In this case, a separate conducting sheet (10) is used for for

the three mobile systems whereas the counterpoise is common to all the three antennas. Both conducting sheet (10) and counterpoise are connected thought a conducting strip. Each conducting sheet (10) is fed by a separate pin.

Figure 5: Example of space-filling perimeter of the conducting sheet (10) to achieve an optimized miniaturization of the mobile telephony antenna (6).

Figure 6: Another example of space-filling perimeter of the conducting sheet (10) to achieve an optimized miniaturization of the mobile telephony antenna (6).

Figure 7: Example of miniaturization of the satellite GPS patch antenna using a space-filling or multilevel antenna technique. The GPS antenna is formed by two parallel conducting sheets spaced by a high permittivity dielectric material, forming a microstrip antenna with circular polarization. The circular polarization is obtained either by means of a two-feeder scheme or by perturbing the perimeter of the patch. The superior conducting sheet (11) perimeter is increased by confining it in space filling curve.

Figure 8: Another example of miniaturization of GPS patch antenna where the superior conducting sheet (11) perimeter is a space-filling curve.

Figure 9: Another example of miniaturization of GPS patch antenna where the superior conducting sheet (11) perimeter is a space-filling curve.

Figure 10: Another example of miniaturization of GPS patch antenna where the perimeter of the inner gap of the superior conducting sheet (11) is a space-filling curve.

Figure 11 presents another preferred embodiment wherein at least two space-filling antennas are supported by the same surface, one space-filling antenna for receiving radio broadcasted signals, preferably within the AM and FM or DAB bands, and the other second space-filling antennas for transmitting and receiving in the cellular telephony bands such as for instance the GSM. All the space-filling antennas are connected at one end to one of the wires of a two-conductor transmission line such as for instance a coaxial cable, being the other conductor of transmission line connected to the metallic car structure.

Figure 12 presents an alternative position of GPS antenna (7). The antenna is placed in an horizontal position, inside the external housing (16) of an external rearview mirror.

Figure 13: Another example of space-filling antenna, based of a SZ curve, for AM/FM reception. The antenna is fed as a monopole and is placed inside a rearview mirror support.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention describes an integrated multiservice antenna system for vehicle comprising at least one miniature antenna characterized by a space-filling curve.

Figure 1 describes one of the preferred embodiments of the present invention. The antenna system is integrated inside an interior rearview mirror base support (1) and the inside rearview mirror housing (2). The system is completed by the mirror (3) and the mirror-frame (4) to maintain it closed. In this configuration, the mirror base support (1) is represented following a vertical extension. Such a particular mirror assembly is shown for the understanding of the invention but it does not constitute an essential part of the invention. As it is readily seen by those skilled in the art, other base support shapes can be used within the same scope and spirit of the present invention.

The antenna system comprises a space-filling antenna (5) suitable for radio broadcasted signals reception, AM and FM or DAB bands, a set of miniature antennas (6) suitable for transmission and reception of cellular telephony signals, the GSM 900, GSM 1800 and UMTS bands, and a miniature patch antenna (7) for GPS signal reception. The space-filling antenna (5) is characterized by a conducting strip (9) which describes a space-filling curve. This space-filling curve is composed by at least two-hundred segments said segments forming a right angle with each adjacent segment, being said segments smaller than a hundredth of the free-space operating central wavelength. The conducting

strip (9) can be supported by any class of low loss dielectric materials including flexible or transparent boards. In this embodiment, one arm of the conducting strip is connected to a first conductor of a two-conductor transmission line, being the second conductor connected to the metallic structure of the vehicle, said metallic structure acting as a metallic counterpoise. Although the space-filling shape of the antenna and its use for receiving radio broadcast is part of the essence of the invention, it is apparent to those skilled in the art that the length of the space-filling curve can be scaled using conventional techniques to obtain a best matching impedance in the VHF band. Depending on the chosen scale, said antenna can be made appropriate either for FM/AM or DAB/AM reception. Comparing to the habitual length of external quarter-wavelength monopole, the size of said space-filling antenna is reduced at least by a factor of five, that is, the final size is smaller than a 20% of a conventional antenna. Fed as a monopole, this antenna observes a similar radiation pattern to a conventional elemental monopole, i.e. a fairly omnidirectionnal monopole in the perpendicular direction of the antenna. The position inside the mirror base support (1) offers a wide open area, assuring a correct reception from all directions. Like any other reception systems, the signal quality can be improved using diversity techniques based on space diversity (using several similar antennas for receiving the same signal) or polarization diversity (exciting orthogonal current modes within the same antenna structure).

Together with the space-filling antenna (5), this example of preferred embodiment of the multiservice antenna system comprises a miniature cellular telephony antenna subsystem for transmitting and receiving GSM 900, GSM 1800 and UMTS. The antennas (6) are characterized by a first planar conducting sheet (10), said sheet being smaller than a quarter of the operating wavelength, and a second parallel conducting sheet (8) acting as a ground counterpoise. In the present embodiment, the antennas are sharing the same ground counterpoise (8), said ground counterpoise being juxtaposed or close to the mirror (3). Both conducting sheet (10) and ground counterpoise (8) are connected through a conducting strip. The conducting sheet (10) is fed by means of a vertical conducting pin coupled either by direct ohmic contact or by capacitive coupling. The antenna polarization is mainly vertical, allowing a good penetration of the signal inside the car. The antennas are optionally combined by means of diplexer or triplexer filter with a single transmission line connected to the input of said diplexer or triplexer. Said diplexer or triplexer can be realized using concentrated elements or stubs but in any case is supported by the same ground counterpoise (8). Moreover, on the same board, additional electronic circuits can be included, like for example an electro-chromic system or a rain detector. The radiation pattern of such antenna is similar to conventional patch antenna, assuring a fairly omnidirectionnal pattern in the horizontal plane. However, the position of the antennas (6) oriented to the front windshield and the ground counterpoise (8), juxtaposed to the mirror (3), limits the power radiated inside the car,

especially in the direction of the head of the driver, reducing any possible interaction or biological effect with the human body while reducing at the same time interferences with other electronic devices.

The antenna system is completed by a satellite antenna such as a GPS antenna (7). Said GPS antenna (7) consists on two parallel conducting sheet (spaced by a high permittivity dielectric material) forming a microstrip antenna with circular polarization. The circular polarization can be obtained either by a two-feeder scheme or by perturbing the perimeter of the superior conducting sheet (11) of the antenna. The GPS antenna (7) also includes a low-noise high-gain pre-amplifier (12). This amplifier is included on a chip such as for instance those proposed by Agilent or Mini-Circuits (series HP58509A or HP58509F for instance). The chip is mounted on a microstrip circuit side by side with the microstrip GPS antenna such that both the antenna and the circuit share the same conducting ground plane. A major difference of the GPS system with the radio or the cellular telephony is that a GPS antenna requires an open wide radiation pattern in the vertical direction. An adequate position is to place this antenna in the mirror base support (1), in a substantially horizontal position. Eventhough the antenna position presents a slight inclination with respect to the horizontal, the radiation pattern of such microstrip antenna is sufficiently omnidirectionnal to assure a good reception from multiple satellite signals over a wide range of positions.

As it is clear to those skilled in the art, the novelty of the antenna system invention is based on choosing a very small, low cost, flat space-filling antenna for radio reception, in combining said space-filling antenna with other miniature antennas for wireless cellular services and satellite services, and packaging them all inside a small plastic or dielectric housing attached on a glass window. In this particular embodiment, the inside rearview mirror is chosen advantageously as a housing for the whole antenna system owing to its privileged position in the car (wide open visibility for transmitting and receiving signals, close position to the control panel of the car) and insignificant visual impact on the car design; nevertheless it is apparent to those skilled in the art that the same basic antenna system can be integrated in other car components such as for instance a rear brake-light without affecting the essential novelty of the invention.

Presented in Figure 2, another similar configuration that can be used within the scope of the present invention include, for instance: placing the wireless cellular antennas (6) inside the support of the mirror structure (1) around the main radio broadcast space-filling antenna (9); integrating two of the wireless cellular services into a standard dual-band antenna and placing it either inside the mirror housing (2) or mirror support (1) ; removing at least one of the antenna components for the antenna system in case one or more of the services is not required for a particular car model or car family; or redesigning circularly polarized satellite antenna (7) for other

frequencies and satellite applications than GPS (such as for instance Iridium, GlobalStar or other satellite phone or wireless data services) using conventional scaling techniques.

Figure 3 describes a preferred embodiment for the space-filling antenna (5) used as AM/FM signal reception. In this case, the conducting strip (9) describes a space-filling curve according to the definition in the present invention. The conducting strip (9) can be for instance printed using standard techniques on a low cost thin dielectric material such as glass fiber or polyester which acts as a support of the antenna. In a preferred embodiment, this configuration is fed with a two conductor structure such as a coaxial cable, with one of the conductors (13) connected to the conducting strip (13) of the space-filling antenna and the other conductor (14) connected to the metallic structure of the car (15), acting as ground counterpoise. The other side of the conducting strip (9) can be left without any connection or can be connected to a specific load or to the same vehicle structure (15) to modify its impedance matching features, yet keeping the same essential space-filling structure as the core of the invention. The antenna is placed in the rearview mirror support (1), parallel to the windshield to assure an orientation close to the vertical. Since this antenna is small comparing with the operating wavelength, the radiation pattern observes a maximum radiation in the plane perpendicular to the antenna orientation, in the horizontal plane in this case, which yields an optimum coverage for receiving terrestrial radio broadcasted signals.

Figure 4 describes another preferred embodiment where the set of miniature antennas for GSM 900, GSM 1800 and UMTS are distributed onto a common conducting ground counterpoise (8). The size and shape of the conducting sheet (10) is designed using standard well-known techniques to ensure a good impedance matching within the desired band. Each conducting sheet (10 presents a dimension lower than a quarter-wavelength o: the operation frequency. This notable size reduction i. due to the presence of a conducting strip between th conducting sheet (10) and the ground counterpoise (8) This configuration is fed by means of a vertica conducting pin coupled either by direct ohmic contac or by capacitive coupling to the conducting sheet (10) The radiation pattern of such antenna is similar to th radiation pattern of a conventional patch antenna presenting a major wide open lobe in the directio: perpendicular to the conducting sheet (10), th horizontal plane in this case. Also, due to the reduce dimensions of the ground plane (8), radiation occurs i: the opposite direction, assuring a fairl omnidirectionnal pattern. It is clear to those skille in the art, that the relative position of the antenna is not important and can be changed without affectin the essence of the present invention.

Presented in Figure 5 there is an improvement o any of the precedent embodiments that can be obtaine by shaping at least a part of the perimeter of sai conducting sheet (10) with an space-filling curve. A the resonant frequency of such a configuration depend of the total length of the perimeter, the improvemen

of the perimeter length using a space-filling perimeter reduces the total size of the conducting sheet (10). Other space-filling curves besides the one displayed in Fig.5 can be used to increase the perimeter length within the same scope and spirit of the present invention. An important advantage of using a space-filling perimeter is that the resonant frequency is changed yet keeping the rest of the antenna parameters (such as the radiation pattern or the antenna gain) practically the same, which allows a size reduction (together with a cost and weight reduction) with respect to the previous embodiment.

As mentioned other space-filling curves can be used within the spirit of the present invention, as shown in Figure 6.

In Figures 7 to 10 several preferred embodiments are presented for a further miniaturization of the satellite antenna (7). In this case, the perimeter of the patch which characterizes the microstrip antenna is advantageously shaped by a space-filling curve.

Figure 7 presents a preferred embodiment for a GPS antenna, characterized by its space-filling perimeter constructed with 20 segments. The shape can also be seen as a multilevel structure formed by 5 coupled squares. Except for the conducting sheet (11) shaping the patch, the antenna design remains similar as the conventional patch rectangular antenna. The circular polarization can be obtained either by a two-feeder scheme or by perturbing the perimeter of the superior conducting sheet (11) of the antenna, using the same

conventional technique as a rectangular conducting sheet (11). The antenna also includes a low-noise high-gain pre-amplifier (12), mounted on a microstrip circuit side by side with the microstrip GPS antenna such that both the antenna and the circuit share the same conducting ground plane. The antenna is placed in the mirror base support (1) in a substantially horizontal position to ensure a broad, almost hemispherical coverage for the multiple satellite link.

Other preferred embodiment is presented in Figure 8. In this case, a similar space filling scheme as the one applied in the precedent embodiment is used for each of the four squares at the corners. The size reduction of such antenna is beyond a 50 %, decreasing the antenna cost due to the area reduction of the high permittivity dielectric material supporting the microstrip antenna configuration. The radiation pattern of such antenna is kept in the same basic shape as a conventional microstrip antenna, ensuring an almost hemispherical coverage in the upper semi-space.

In Figure 9 and 10, other space-filling curves are used to shape the perimeter of the conducting sheet (11) of the satellite antenna. It will be apparent to those skilled in the art, that similar techniques such as the above can also be applied to the wireless cellular antennas within the scope of the present invention.

In Figure 9, the external perimeter is conformed by another space-filling curve. In Figure 10, an aperture is realized in the center of the conducting

sheet (11). The length of said aperture is increased by a space-filling curve following a similar pattern as the one in Fig.9. In both cases, the antenna size is reduced maintaining the circular polarization and the radiation pattern.

In Figure 11, another preferred embodiment is presented. The antenna system is placed in a substantial vertical position inside the mirror support (1), or parallel to the glass window to minimize the thickness of said support (1). In this preferred embodiment, one space-filling antenna is characterized by a conducting strip (9) composed by at least two-hundred segments. Said segments form a substantially right angle with each adjacent segment, and are smaller than a hundredth of the free-space operating central wavelength. This antenna is suitable for radio broadcasted signals reception, such as for instance AM and FM or DAB bands. The conducting strip (9) can be supported by any class of low loss dielectric materials including flexible or transparent boards. The system is completed by other space-filling antennas, with a conducting strip (9) that also describe a space-filling curve, although the number of segments is made smaller with respect to the previous one. These other space-filling antennas are designed for GSM 900, GSM 1800 and UMTS transmission and reception. In this embodiment, a first conductor of a two-conductor input transmission line is connected to each conducting strip (9) while the second conductor is connected to the conducting structure of the vehicle, said conducting structure acting as the metallic counterpoise of the monopole configuration. Being very small compared to the

wavelength, these antennas observe a similar radiation pattern to that of a conventional elemental monopole, i.e. a substantially omnidirectionnal pattern on the horizontal plane. The position inside the mirror base support (1) offers an advantageous wide open visibility, assuring a correct reception from virtually any azimuthal direction. It is clear to those skilled in the art, that the same innovative space-filling shapes disclosed in the present invention can be advantageously used in any diversity technique (such as space of polarization diversity) aiming to compensate signal fading due to a multipath propagation environment. The small size of said space-filling antennas allows an easy integration of the antenna in multiple parts of the motor vehicle such as for instance, the rear brake-light housing mounted upon the rear window, or the dark sun-protection band that frames windows in a broad range of car models. Any of these configurations are compatible with the preferred embodiments shown in the present invention and share with them the same essential innovative aspect.

Alternative position of GPS antenna (7) is presented in Figure 12. The important size reduction achieved by confining the perimeter of the conducting sheet (11) in a space-filling curve allows alternative positions to that presented in Figure 1. In Figure 12, the GPS antenna (7) is placed in an external rearview mirror housing (16), in a substantially horizontal position. Placed in the top part of the housing (16), no obstacle blocks the vertical visibility of the antenna. The presence near the antenna of metallic pieces of the car bodywork does not affect the good

reception of GPS signals even if some signals are reflected. The right circular polarization of the GPS antenna cancels all other signals received at the same frequency with different polarizations. In particular, reflected satellite signals suffer from a strong polarization change and therefore do not interfere with the circularly polarized directly incoming signals. Together with the antenna, a low-noise amplifier is optionally mounted on the a microstrip circuit side by side with the microstrip GPS antenna such that both the antenna and the circuit share the same conducting ground plane.

Figure 13 describes another preferred embodiment used for AM/FM reception. In this case, the conducting strip (9) describes another space-filling curve according to the definition in the present invention. This configuration is also fed with a two conductor structure such as a coaxial cable, with one of the conductors (13) connected to the conducting strip (13) of the space-filling antenna and the other conductor (14) connected to the metallic structure of the car (15), acting as ground counterpoise. The other side of the conducting strip (9) can be left without any connection or can be connected to a specific load or to the same vehicle structure (15) to modify its impedance matching features, yet keeping the same essential space-filling structure as the core of the invention. The antenna is placed in the rearview mirror support (1), parallel to the windshield to assure an orientation close to the vertical. Since this antenna is small comparing with the operating wavelength, the radiation pattern observes a maximum radiation in the

plane perpendicular to the antenna orientation, in the horizontal plane in this case, which yields an optimum coverage for receiving terrestrial radio broadcasted signals.

It seems obvious that each of the antennas incorporated in the integrated multiservice antenna ~~systems~~ object of the present invention, could be individualized and put into practice itself keeping the features previously described, this possibility is specially suitable for low or medium class vehicles, in which only one of the antennas is installed.

Having illustrated and described the principles of our invention in several preferred embodiments thereof, it should be readily apparent to those skilled in the art that the invention can be modified in arrangement and detail without departing from such principles. We claim all modifications coming within the spirit and scope of the accompanying claims.

CLAIMS

1.- Integrated multiservice antenna system, specially designed to be easily installable in any type of motor vehicle, characterized in that it comprises a combination of two or more of a radio-receiving antenna for the AM, FM and/or DAB band, a transmitting-receiving antenna for cellular telephony in the GSM and/or UMTS bands, and/or an antenna for satellite-signals, preferably satellite-navigations systems such as GPS, such that said combination is integrated within a dielectric cover capable to be installed in any type of motor vehicle, said cover being a cover provided for an inside or an outside rear-view mirror, the system remaining entirely hidden;

said radio-receiving antenna consisting of a space-filling miniature antenna formed by a space-filling curve provided in at least a part of a metallic strip or wire which forms an arm of said antenna, this arm being connected at one end to one of the wires of a two-conductor transmission line, such as for instance a coaxial cable or similar, being the other conductor of said transmission line connected to the metallic car structure, the last acting as a ground counterpoise for the whole system;

said telephony antenna consisting of a miniature cellular telephony antenna system, each of said antennas being formed by a first planar conducting sheet smaller than a quarter of the operating wavelength, said first planar conducting sheet being parallel to a second conducting sheet acting as a ground counterpoise, both sheets being connected through a conducting strip with one tip of said strip

connected to one edge of said first conducting sheet and the other tip connected to a point of the ground counterpoise, being said antennas fed by means of a vertical conducting pin coupled either by direct ohmic contact or by capacitive coupling to said first conducting sheet; and

said satellite-signal antenna consisting of two parallel conducting sheets spaced by a high permittivity dielectric material, said conducting sheets and said dielectric material forming a microstrip antenna with circular polarization obtained either by means of two-feeder scheme o by perturbing the perimeter of the patch.

2.- Integrated multiservice antenna system according to claim 1, characterized in that the space-filling curve is at least composed by two-hundred connected segments, said segments forming a substantially right angle with each adjacent segment, being said segments smaller than a hundredth of the free-space operating central wavelength.

3.- Integrated multiservice antenna system according to claim 1, characterized in that the satellite-signal, for instance GPS, antenna is a miniature microstrip patch antenna featured by its perimeter, wherein at least a part of said perimeter is shaped as a space-filling curve or a multilevel structure.

4.- Integrated multiservice antenna system according to claim 1, characterized in that the dielectric cover is attached to the corner, top or

bottom part of the inner surface of the rear or front window.

5.- Integrated multiservice antenna system according to claim 1, characterized in that the dielectric cover also integrates a warning light or a rain detector or a collision preventing sensor or any combination of them.

6.- Integrated multiservice antenna system according to claim 1, characterized in that the telephony antenna is formed by a first planar conducting sheet smaller than a quarter of the operating wavelength, said first planar conducting sheet featured by its perimeter, wherein at least a part of said perimeter is shaped as a space-filling curve, being said sheet parallel to a second conducting sheet acting as a ground counterpoise, both sheets being connected through a conducting strip with one tip of said strip connected to one edge of said first conducting sheet and the other tip connected to a point of the ground counterpoise, being said antennas fed by means of a vertical conducting pin coupled either by direct ohmic contact or by capacitive coupling to said first conducting sheet;

7.- Integrated multiservice antenna system according to claim 1, characterized in that at least a telephony antenna is formed by a space-filling curve provided in at least a part of a metallic strip or wire which forms an arm of said antenna, this arm being connected at one end to one of the wires of a two-conductor transmission line, such as for instance a

coaxial cable or similar, being the other conductor of said transmission line connected to the metallic car structure, the last acting as a ground counterpoise for the whole system;

AMENDED CLAIMS
[received by the International Bureau on 5 February 2002 (05.02.02);
original claim 1 amended; new claim 8 added;
remaining claims unchanged (4 pages)]

1.- Integrated multiservice antenna system, specially designed to be easily installable in any type of motor vehicle, characterized in that it comprises a combination of two or more of a radio-receiving antenna for the AM, FM and/or DAB band, a transmitting-receiving antenna for cellular telephony in the GSM and/or UMTS bands, and/or an antenna for satellite-signals, preferably satellite-navigations systems such as GPS, such that said combination is integrated within a dielectric cover capable to be installed in any type of motor vehicle, the system remaining entirely hidden;

said radio-receiving antenna consisting of a space-filling miniature antenna formed by a space-filling curve provided in at least a part of a metallic strip or wire which forms an arm of said antenna, this arm being connected at one end to one of the wires of a two-conductor transmission line, such as for instance a coaxial cable or similar, being the other conductor of said transmission line connected to the metallic car structure, the last acting as a ground counterpoise for the whole system;

said telephony antenna consisting of a miniature cellular telephony antenna system, each of said antennas being formed by a first planar conducting sheet smaller than a quarter of the operating wavelength, said first planar conducting sheet being parallel to a second conducting sheet acting as a ground counterpoise, both sheets being connected through a conducting strip with one tip of said strip connected to one edge of said first conducting sheet

and the other tip connected to a point of the ground counterpoise, being said antennas fed by means of a vertical conducting pin coupled either by direct ohmic contact or by capacitive coupling to said first conducting sheet; and

said satellite-signal antenna consisting of two parallel conducting sheets spaced by a high permittivity dielectric material, said conducting sheets and said dielectric material forming a microstrip antenna with circular polarization obtained either by means of two-feeder scheme o by perturbing the perimeter of the patch.

2.- Integrated multiservice antenna system according to claim 1, characterized in that the space-filling curve is at least composed by two-hundred connected segments, said segments forming a substantially right angle with each adjacent segment, being said segments smaller than a hundredth of the free-space operating central wavelength.

3.- Integrated multiservice antenna system according to claim 1, characterized in that the satellite-signal, for instance GPS, antenna is a miniature microstrip patch antenna featured by its perimeter, wherein at least a part of said perimeter is shaped as a space-filling curve or a multilevel structure.

4.- Integrated multiservice antenna system according to claim 1, characterized in that the dielectric cover is attached to the corner, top or

bottom part of the inner surface of the rear or front window.

5.- Integrated multiservice antenna system according to claim 1, characterized in that the dielectric cover also integrates a warning light or a rain detector or a collision preventing sensor or any combination of them.

6.- Integrated multiservice antenna system according to claim 1, characterized in that the telephony antenna is formed by a first planar conducting sheet smaller than a quarter of the operating wavelength, said first planar conducting sheet featured by its perimeter, wherein at least a part of said perimeter is shaped as a space-filling curve, being said sheet parallel to a second conducting sheet acting as a ground counterpoise, both sheets being connected through a conducting strip with one tip of said strip connected to one edge of said first conducting sheet and the other tip connected to a point of the ground counterpoise, being said antennas fed by means of a vertical conducting pin coupled either by direct ohmic contact or by capacitive coupling to said first conducting sheet;

7.- Integrated multiservice antenna system according to claim 1, characterized in that at least a telephony antenna is formed by a space-filling curve provided in at least a part of a metallic strip or wire which forms an arm of said antenna, this arm being connected at one end to one of the wires of a two-conductor transmission line, such as for instance a

coaxial cable or similar, being the other conductor of said transmission line connected to the metallic car structure, the last acting as a ground counterpoise for the whole system.

8.- Integrated multiservice antenna system according to claim 1, characterized in that said cover is provided for an inside or an outside rear-view mirror.

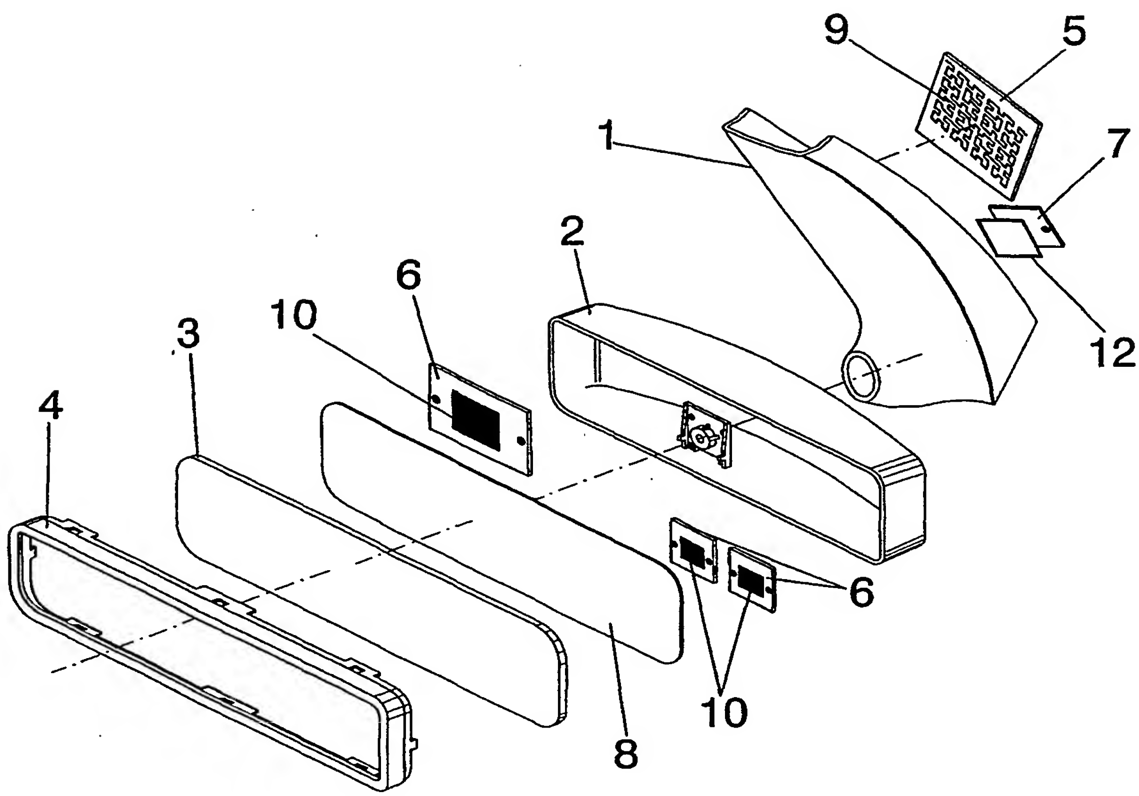


FIG. 1

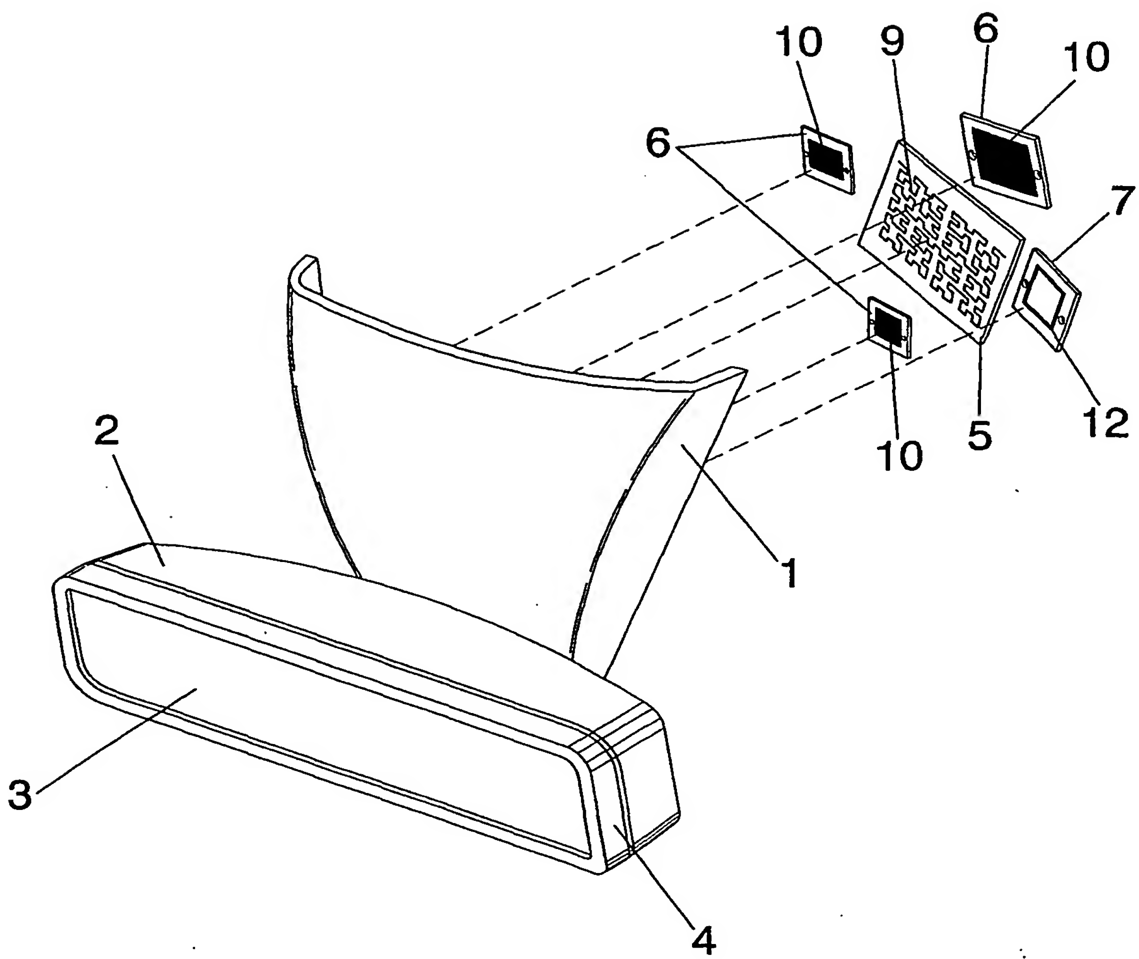


FIG. 2

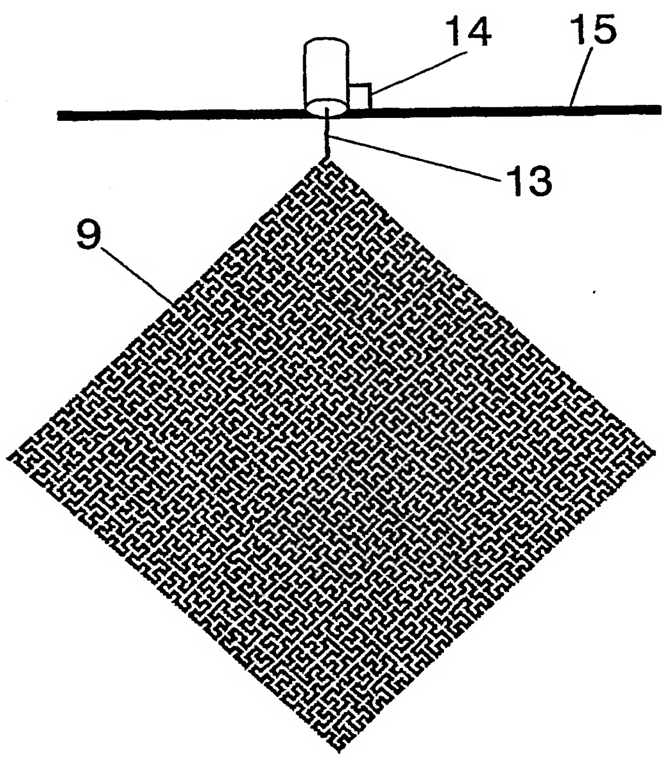


FIG. 3

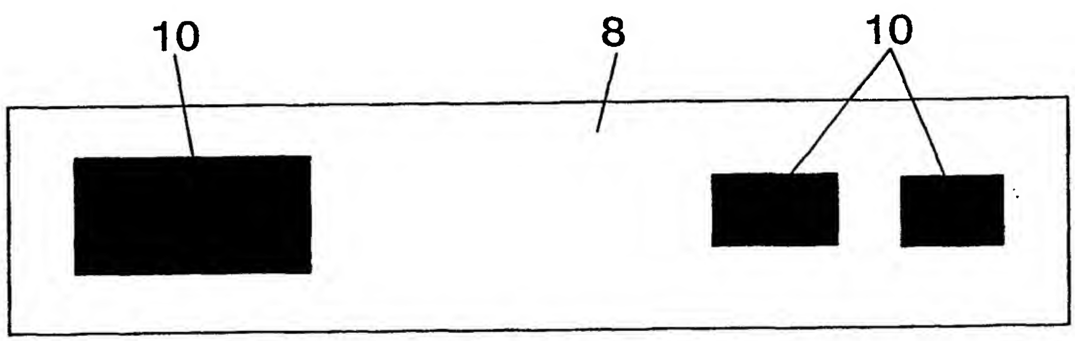


FIG. 4

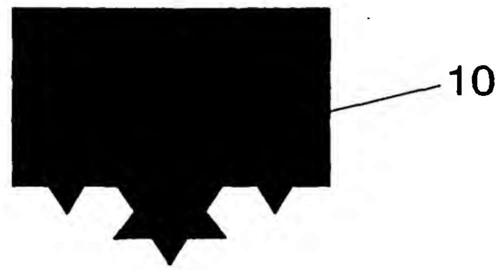


FIG. 5

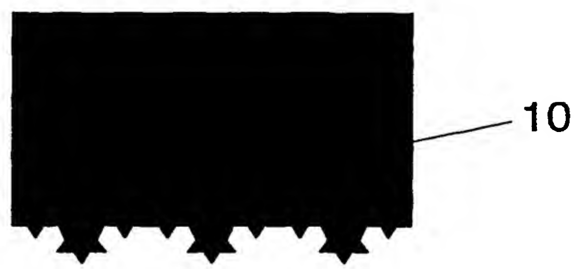


FIG. 6

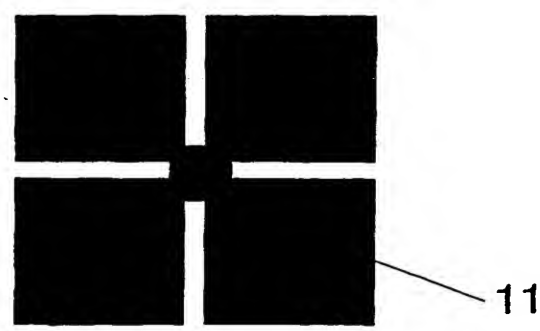


FIG. 7

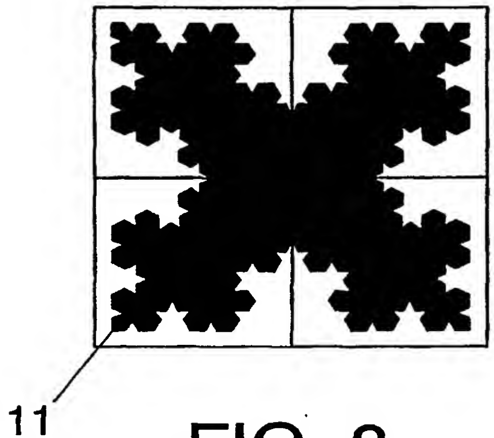


FIG. 8

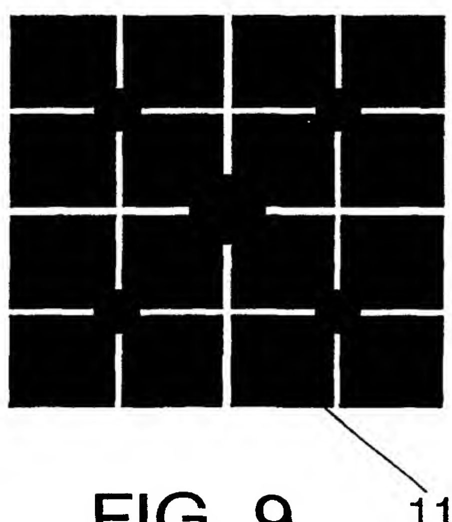


FIG. 9

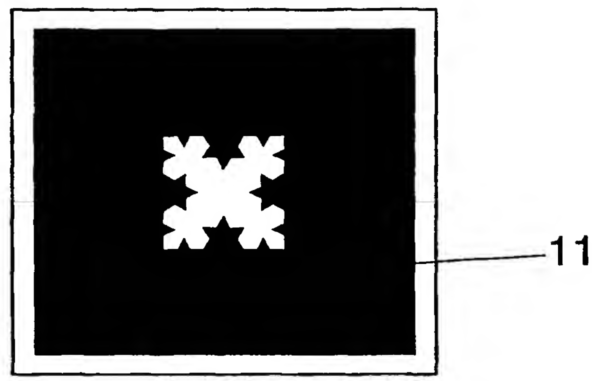


FIG. 10

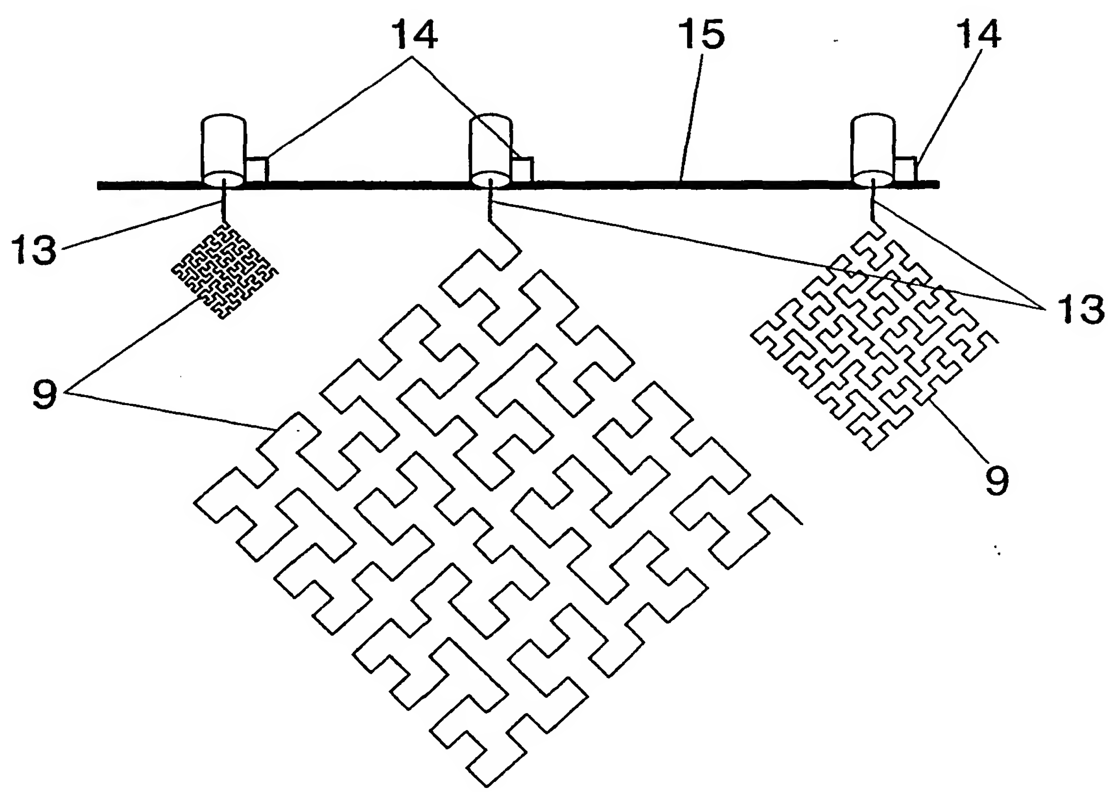


FIG. 11

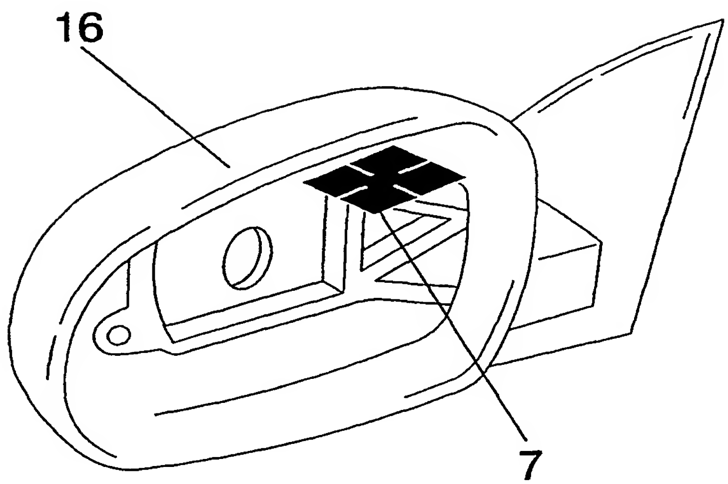


FIG. 12

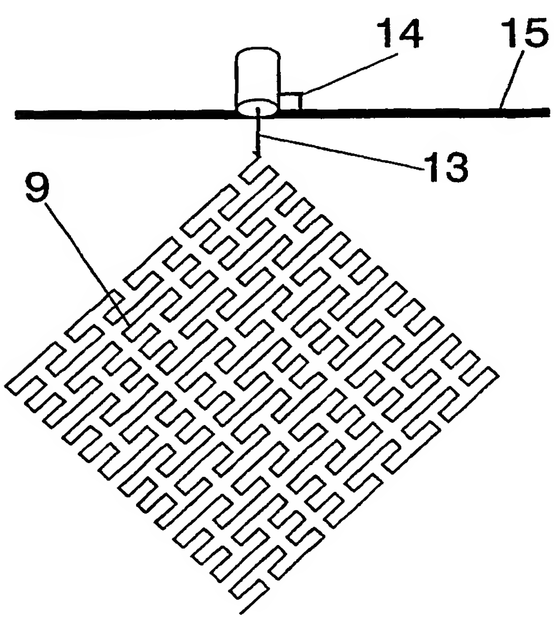


FIG. 13

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/10562

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q1/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 798 688 A (SCHOFIELD KENNETH) 25 August 1998 (1998-08-25) cited in the application column 3, line 6 -column 4, line 22; figure 2	1-7
X	WO 96 29755 A (ELDEN INC) 26 September 1996 (1996-09-26) page 8, line 7 -page 11, line 20; figures 1-6	1-7
X	WO 00 49680 A (GENTEX CORP) 24 August 2000 (2000-08-24) page 8, line 19 -page 10, line 4; figure 3	1-7

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 January 2001	06/02/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Villafuerte Abrego

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/10562

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5798688	A	25-08-1998	EP	0860325 A	26-08-1998
WO 9629755	A	26-09-1996	US	5649316 A	15-07-1997
			AU	5421196 A	08-10-1996
			US	5634209 A	27-05-1997
WO 0049680	A	24-08-2000	US	6166698 A	26-12-2000